Paper presented in the VI Globelics Conference at Mexico City, September 22-24 2008

Globelics

The Brazilian System of Innovation for Ethanol Fuel:
An Essay on the Strategic Role of the Standardization Process

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ABSTRACT

This paper presents the results of a case-study on the importance of the standardization process for the Brazilian system of innovation for ethanol fuel. The analysis on its evolution also shows evidence of the strategic role of the State to enjoy the oportunities opened during a paradigmatic change, as we defend to have started during the energy crisis in the 1970s, when the Brazilian government started setting-up the policies for the ethanol fuel sector. The standardization process gains attention in the recent context, in face of the strategy of transforming the product into an international commodity. The main contribution of this paper is therefore to call attention to the need – at odds with more conservative perspectives – that developing countries invest in industrial, technological and pro-innovation policies in order to promote their development, according to their particular interests and taking into account the investment on activities involved in the standardization process.

Key-words: system of innovation, windows of opportunity, ethanol fuel, standaridization process, Brazilian experience.

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Introduction

Biofuels is a recent subject in the economic literature which has been raising a lot of interest due to its strategic role in the energetic sector. Since the oil crisis in the 1970s, oil production faces growing instabilities, raising concerns in importing countries like USA and Europe Union who are in a constant search for reducing their dependency on this fuel. Therefore, the scale production of biofuels has definitely entered technical and political discussions all over the world, aiming at diversifying the energy matrix of countries.

The lading role of Brazil in the production of biofuels – specially ethanol, since the 1970s in economy scale – must be emphasized. The country enjoyed what in the present work we consider to have been a '*window of opportunity*' (Perez and Soete, 1988) during the oil crisis in the 1970s to envisage the 'Proalcool', a program that invested significant resources for the ethanol industry.

It is in this context that Brazilian firms, supported by the government, have been able to, along the last thirty years, develop a strong competitiveness in the ethanol fuel production and when a '*new*' window of opportunity appears with the debate about environment protection and the need for alternative sources of energy in 2000s, Brazil shows a leading role. It is fundamental, then, to analyze how did the country manage to build a sustainable national system of innovation for ethanol fuel along these years.

In the international arena, the Brazilian experience deserves attention. Given the interest in the consumption of ethanol by many countries with the aim of 'greening' their energy matrix, the issue now has moved to the forefront strategy of turning ethanol into a fully fledged world commodity. For that, two main pre-condition remain. First, the need of increasing the number of producers, and therefore, of suppliers of ethanol in order to avoid undersupply crisis. The second concerns the need of having internationally harmonized specifications for the product, through the standardization process.

It is this second pre-condition that lays in the core of the proposed analysis, in which the leading role of Brazil shall be the main focus. The hypothesis of the article is therefore that the standardization process poses some important analytical aspects to any national system of innovation with impacts over the innovative capacity and the competitiveness of firms. Despite its importance, the matter has not been included in the main NSI analysis. With the aim of contributing to the fulfillment of this blank, emphasis shall be put on those activities of developing primary measurement standards, which lays on the basis of standardization and is by its nature an activity intensive on research and development (R&D) investment.

The objective of the present article is then twofold. Firstly to discuss, through the analysis of case-study of Brazilian ethanol fuel sector, the importance of standardization and related activities to its NSI. And secondly present an analysis of it as a case in which a developing country managed to enjoy a '*window of opportunity*' and make the necessary investments for the development of a technology to suit its specificities – with a strong support from government agencies –, and even become a leading actor in the international scenery.

With the aim of discussing the above questions, the article is divided into four sections. The first one presents the main theoretical aspects to be the basis of the present proposal. It is in this section that the NSI approach and some of the main contributions of the neo-schumpeterian approach to the proposed analysis shall be presented. The second section is then dedicated to a deeper analysis of the Brazilian ethanol fuel industry, reporting its historical evolution that resulted on the construction of a sustainable NSI for the sector, what allowed a leading role in the international scenery. The third section is then proposed with the objective of discussing, through the combination of the theoretical aspects inserted on section one and the empirical analysis of section two, the importance of standardization to the Brazilian system of innovation for ethanol fuel. For that, we shall present the main findings of the case-study, with the industry's and other important actors' views.

The concluding remarks will be provided in section four, where some proposals are made to the wider biofuels sector and also to future policies formulation in developing countries, in which strategies related to the standardization process can not be neglected.

1. Theoretical Framework: from the Neo-schumpeterian Approach and NSI Perspectives

Both classical and neoclassical theories have been historically inefficient at the provision of satisfactory explanations for international trade flows as much as for the imbalance of economic growth and development. Nevertheless, according to Dosi and Soete (1988), a new tendency in interpretations may be observed and even those more conservative theoreticians have been showing an attempt at improving their theories, getting closer to those ones that take technological factors into consideration, treated until then as exogenous variables. Their analysis start including, therefore, arguments in defense of the fundamental character represented by different technological levels and innovative capabilities for explaining not only imbalances but also tendencies in trade and income of each country.

Less conservative perspectives therefore understand the development phenomenon not as a harmonic and naturally converging process but characterized by uncertainties and asymmetries. Underdevelopment can not be seen as a mere stage towards the development process – on the other hand they both should be seen as aspects of one same historical process, associated to the creation and diffusion of modern technology (Furtado, 2003 *apud* Cassiolato *et al*., 2005).

Adopting a perspective convergent to Mani (2004), we sustain that the importance of concentrating analytical efforts on the case of less developed countries is justified by the need of overcoming the mistaken idea of some actors who conceive this group of countries as mere assemblers and imitators of technologies imported from advanced countries. It means overcoming the conservative point of view that incorrectly defends that lees developed countries' firms should not commit resources with R&D – unless when limited to an adaptive character –, since they claim that such strategy would merely represent a 'reinvention of the wheel'. Under this conservative perspective less developed countries should open their production and trade regimes, what would guarantee the entrance of technology flows in their economies[3].

[3] According to Bell and Pavitt (1993, p. 158): "in economies that are so-called 'borrowers' of ready-made technology from more technologically advanced economies, technological accumulation is misrepresented as a process of accumulating technology that is largely embodied in physical capital, (...), we shall argue that policies which continue to rest on these perceptions of the processes of technological accumulation and technical change are likely to hinder rather than hasten industrial 'catching up'".

As pointed out by Tavares (1972), though, technology imported by less developed countries has been developed according to the reality of advanced economies, diverging from their own reality. These countries should then invest for the creation of new techniques adequate to their particular conditions. About this same subject Anciães (1978) states that the failure in developing technologies in areas where the techniques of more advanced countries do not apply (as for example in tropical agriculture), is one of the heritages of underdevelopment with origins at technological dependence. It becomes important, therefore, to bring the issues raised here to the debate concerning the catching-up process of these countries, searching for means that reduce gaps between less developed countries and the most advanced ones.

Perez e Soete (1988) propose the adoption of certain strategies by less developed countries, to be pursued through the acquisition of the capacity of participating in the generation and improvement of technologies, as opposed to the mere use of them, what means being able to enter the market whether as early imitators or innovators of products and processes. The more distant they are from technological frontier, the greater the barriers for their insertion in a new paradigm (Cassiolato *et al*., 2005).

To fully understand the proposal of Perez and Soete, it is necessary to bring out the discussion about the concepts of technological paradigm and trajectory firstly introduced by Dosi (1982). Elaborated from the concept of scientific paradigm proposed by Thomas Kuhn, the concept of 'technological paradigm' acts as a definer of technological research programs. The technological paradigm in force prescribes negative and positive heuristics, indicating directions to be taken or neglected in the technological change process. In other words, the process of searching for innovations can not be treated in a pure stochastic manner. Besides, those long-term aspects of social, economic and institutional structure affect the emergence of new technological paradigms that will then compete with already existing paradigms. There is a trade-off in the transition from one technological paradigm to another, in what refers to the configuration of the productive structures of a country, between exploring new paradigms and 'exploiting' incremental advances in the pre-existent one, given by the diverse possible 'technological trajectories', representing the concrete way in which the technological paradigm evolves, implying change within the same paradigm[4].

Following Dosi's proposal, Perez and Soete (1988) observe that during the transition of paradigms, opportunities are open for countries to enter in the new technology under way, what they call '*windows of opportunity*'. They define four classes of costs that affect the entrance in a certain technological paradigm: fixed costs of investment, cost of scientific and technical knowledge required for assimilating the innovation, cost of acquisition of the necessary experience to deal with innovation and take it to the market and cost of overcoming 'locational' disadvantages, related to general infrastructure and other economic and institutional conditions. The curves that express each of these costs vary over time, resulting in the fact that the total minimum required to enter in a certain paradigm will be either high or low according to how technology evolves throughout the different phases of the product life cycle.

As discussed by Freeman and Soete (1997), the logic of the system works in such a manner to ensure that rich countries get richer and poor ones get poorer – it is an analysis that diagnoses the existence of path-dependence, in which the less developed countries may get stuck

[4] It must be noted that technological paradigms, as well as their trajectories, present decreasing returns, whose crisis comes up from its own success – as the paradigm is used to explain a wider and wider number of problems an insufficiency for the explanation of some of these problems appears, taking it to a crisis.

to existing paradigms, due to the high costs of technological change, what confines them to an inferior level of development. Possibilities to break this vicious cycle comes up through windows of opportunity, when less developed countries have the chance of entering new technologies during transition periods between paradigms.

Nevertheless, Perez and Soete (1988) observe the scarcity of windows of opportunity what: “highlights how ‘non-automatic’ and exceptional such processes of effective technological catching-up are. The use of foreign, imported technology as an ‘industrialization’ short cut depends on having the required conditions to undertake the difficult and complex process involved in its effective assimilation”.

The best manner of enjoying opportunities created, affirm the authors, consists in entering in the technology at the right moment. In order to demonstrate their theory more concretely, they divide the process of developing a new technology into four phases: (I) introduction of innovation, (II) initial growth, (III) advanced growth, and finally (IV) maturity. Perez and Soete conclude, then, that phases (I) and (IV) offer the most favorable conditions for new entrants. Phase (I) for being exactly during the initial stage of a technology that low investment in capital and reduced experience are needed. Phase (IV), on the other side, represents the maturity of the technology, when product and production process are standardized and, consequently, scientific knowledge are already essentially diffused and the demands for local infrastructure no longer represent sound impediments. Entrance in a new paradigm, as observed by the authors, is easier during phase (IV), as the entrance during the first phase is more risky, not guaranteeing the survival of that strategy.

Perez and Soete recognize, though, that the real catching-up process is given by a well-succeeded entrance at an initial stage of paradigmatic change, guaranteeing space in the technological development that may lead to a new level, as has already occurred to many recently industrialized countries, as Japan and other few countries of Southeast Asia, as opposed to phase (IV), when countries are already late. Dosi and Soete (1988, p. 414) ratify this argument, affirming that: “the basic assumption of modern technology-gap trade accounts is that technology is not a freely, instantaneously and universally available good, but that there are substantial advantages in being first”.

Difficulty associated with catching-up processes refers not only to the possession of the necessary attributes to the entrance in a new paradigm, but also to the capacity of perception of opportunities raised, reaffirming the importance of the institutional apparatus, specially in what concerns those related to governmental action in less developed countries, both for the creation of certain advantages for firms to innovate and for compensating the costs involved in the process.

Transition to a new paradigm, therefore, for being complex and costly, can not be made spontaneously by private capital, demanding the support from the public sector. According to Nelson (1990, p. 60):

> *“government agencies are an important part of the modern system. (...). Since World War II they have become the principal founders of university research. In some fields, government agencies are major actors in the development of new products and processes. Where a government agency holds a strong interest in a technology, it may try to coordinate private efforts as well as fund them”.*

Chesnais (1992) supports this point of view, reinforcing that attention must be paid to those aspects related to the infrastructure at the contour of firms, introducing the concept of ‘structural competitiveness’ . Even though he considers that the competitiveness of firms reflects well succeeded management practices, the author singles out that we should also pay attention to those specific economic trends of long-term, technical infrastructure and other factors that determine externalities upon which firms may grow.

In this same direction, Possas (1996) elects three classes of systemic factors that influence competitiveness: (i) those associated to the competitive environment – the whole context around markets: regulation, competitive policies, etc.; (ii) factors connected to externalities – infrastructure, cost of the country, etc.; (iii) institutional-political factors, with reference to horizontal macroeconomic policies: monetary, credit, fiscal, trade.

In his approach, factors directed to the promotion of scientific and technological infrastructure represent one of the most strategic systemic components at the present context – of globalization and high intensity in scientific-base technologies. According to the author, the main function of these factors lays on the promotion of systemic competitiveness through the dilution of high economic risks associated to R&D expenditures and of the stimulus to the obtainment of synergies derived from scientific and technological effort shared among institutions and firms.

Besides, as defended by Dosi, Freeman and Fabiani (1994), there is a sound correlation between the capability of innovating and of quickly adopting new technologies and: (i) the participation at world markets; (ii) per capita income (iii) income growth rates. And they add: “catching-up and forging ahead (itself not a very frequent phenomenon) is associated with explosive export growth in products related to new technologies (including organizational innovations)” (p. 23).

These findings reveal that support from the State is a pivotal mechanism in the promotion of systemic competitiveness, at odds with what liberal discourse defends. This occurs because, among other factors, economic return of investments in infrastructure to generate technology is, besides of difficult determination, quite uncertain (Ferraz, 1989). Such argument finds support in the proposal of Cassiolato and Lastres (2005), who reinforce the irrelevance of neutral policies recommended by international agencies, as is the case of fiscal incentives for R&D – which may end up generating perverse effects by the incitement of inequalities –, as well as of policies that aim at the promotion of a fast modernization through merely importing equipment. It is up to the State the pro-active character directed at the coordination and induction of productive transformation processes, viewing at the internalization of potential benefits proportionated by entering a new technological paradigm.

The above raised questions are at the core of a new perspective that aims at dealing with these new trends – the approach of ‘National Systems of Innovation’ (NSI). Freeman (2003) was the first author to use this concept, when emphasizing the importance of the technological infrastructure for international competitiveness. In this approach, emphasis is dedicated to the complex nature of agents who exert influence over the innovative process as a whole – including the generation, the selection and the diffusion of innovations. In accordance to this proposal, innovative dynamics must be seen as a process that depends not only on the innovative capacity of individual firms, but also on how they interact with each other and with other actors. As stated by Lundvall (1992, p. 2): “a system of innovation is constituted of elements and relations that interact for the production, diffusion and usage of new, and economically useful knowledge; and the national system comprises elements and relations located or originated within the borders of a national state".

Lundvall (1992, p. 12) distinguishes two types of NSI – a broad definition and a narrow one. The narrow definition includes only organizations and institutions associated to searching and exploration – as R&D departments, technological institutes and universities. The broad definition of NSI on the other side includes all parts and aspects of economic structure and of the institutional framework that affect learning and the processes of searching and exploration – the productive, financial and market systems, for instance, are considered subsystems where learning occurs.

According to this author NSI plays an essential role in the support and guidance of innovation and learning processes, in face of uncertainties inherent to the first and of the importance of the second, demanding complex communication among involved parties. Following Lundvall (1992) proposal, included under a broader definition of the concept, NSI may be decomposed into five main elements: (i) internal organization of firms; (ii) relations among firms; (iii) the role of the public sector; (iv) the institutional framework of the financial sector; (v) R&D intensity as well as its organization (p. 13).

It is interesting to notice that as the concept evolved, the Systems of Innovation approach started being utilized by different analysts under diverse levels of analysis – regional, local, sectoral. For the purpose of the present article the sectoral dimension is the most adequate one (Malerba, 2003), since the analysis is directed to the Brazilian System of Innovation for ethanol fuel. Besides, as will be clearer from now on the present work is directed to an analysis that congregates two of the elements identified by Lundvall, in the Brazilian SI for ethanol fuel: the role of the public sector and of the R&D intensity.

2. Brazilian System of Innovation for Ethanol Fuel

The production process of ethanol fuel may use as raw material the most diverse biomasses. Following Brazilian tradition, the most utilized source for this production in the world is the sugar cane, the most efficient one with regards to energetic profitability. There are two types of ethanol fuel – hydrated and anhydrous[5], being the first one more adequate to vehicles exclusively run on alcohol and the second one to be mixed to petrol gas. Brazil is the most efficient country in the production of ethanol fuel, as can be observed through Table 1.

[5] The first one is not yet very used in foreign markets.

Table 1: Anhydrous Alcohol Production Cost in selected countries

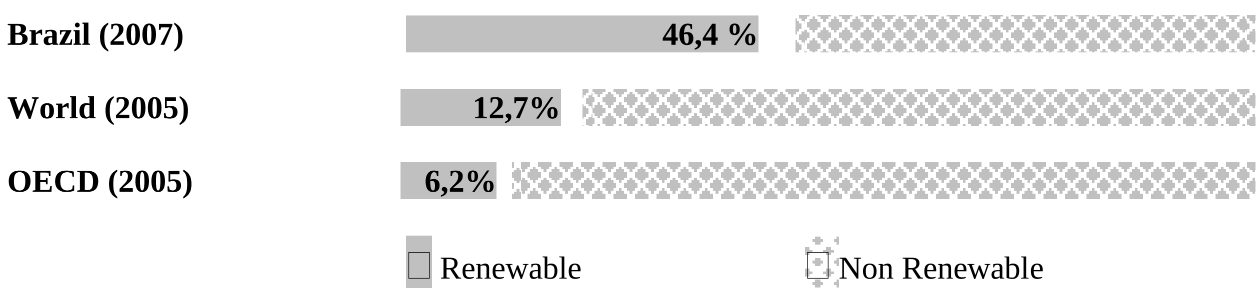
US$ /liter

Country	Anhydrous Alcohol Production Cost	Raw material
Brazil	0,20	Sugar cane
USA	0,47	Corn
Europe	0,97	Beetroot, wheat
Thailand	0,29	Sugar cane
Australia	0,32	Sugar cane

Based on Unicamp (2005, p. 142).

The evolution of the sector in Brazil – as shall be shown afterwards – allowed the country to reach an outstanding position with regards to its energy matrix, in face of other countries in the world. According to preliminary results of the 2008 National Energy Balance (BEN, in Portuguese) (EPE, 2008), products derived from sugar cane reached a new level in the Brazilian energy matrix, assuming the second position among most demanded energetic products in 2007. With this, Brazil increased the participation of renewable sources in its energy matrix, which is now composed of 46,4% of renewable sources, significantly ahead from the rest of the world (Graphic1).

Graphic 1: Domestic Energy Supply: Brazil, World and OECD



Adapted from EPE (2008).

This leading position has brought the ethanol fuel industry to a conjunct of national well-succeeded cases of agro-industry, representing an exception in face of the recent context of the innovative capability of Brazilian economy as a whole, whose performance, according to what Cassiolato and Lastres (2005) argue, remains modest, being the innovative pattern still developed, in its majority, in a defensive and adaptive manner.

Although the first steps for the ethanol fuel sector in Brazil were taken in the beginning of the twentieth century, we sustain that the building-up of a SI for the sector must take into account the setting-up of policies more specific to the sector in the 1970s. It is at this moment, therefore, that one can notice the structuring of some of the bases of the SI for ethanol fuel – even if the concept at that time had not been yet adopted.

Initially, the production of ethanol as a fuel was attached to conjunctural matters, as instabilities in the international market for sugar and restrictions in the import capacity. In the 1970s, two successive oil shocks – the first one in 1973 and the second one in 1979 –, caused an expressive raising in the barrel price, as determined by OPEP, passing from US$ 2,59 to US$ 30,00 during the first half of 1980s (Paixão, 1996).

We sustain the hypothesis that this international energy crisis opened an opportunity for the Brazilian ethanol sector. Although only recently, in 2006, debates on a real paradigmatic change in the field of energy intensified, it seems to us that it was in the 1970s that it first became clear that such change would be necessary in a short horizon of time – passing from technologies that depend on fossil fuels, and therefore scarce, to other technology routes based on renewable sources.

It is at this moment of paradigmatic change that the Brazilian energy model enters into a reformulation process, searching for the reduction of its dependency on oil and derived products. The role of the State in this process has been fundamental – as it is in paradigmatic change moments, as already sustained here –, initiating a whole series of policies aiming at overcoming the 'energy crisis', with emphasis to the development of a new energy matrix of alternative and renewable character, culminating in the establishment of the National Alcohol Program (PNA), or Proalcool. Legitimization of Proalcool was based on regional, economic and social features and for that it counted on sound investments, supported by the World Bank. After that it has been possible to notice the increase in the area dedicated to the plantation of sugar cane as well as the implementation of alcohol distilleries, either autonomous or annexed to existing sugar mills[6].

The evolution of production and usage of alcohol as fuel in large scale in Brazil can be understood through the establishment of four phases (Simões, 2007). The first three ones are related to the consecution of Proalcool, initiating from 1975 to 1979, with the promotion of the addition of anhydrous alcohol to petrol gas, not contemplating significant technological changes in the productive process itself, but demanding an effort for the adaptation of national cars' engines, through some pioneering R&D investments in the country and abroad.

The second phase of Proalcool was launched in 1979 in the middle of a crisis in the international scenery, which served as stimulus for enlarging the Program. This period reflected the peak of the Program, with the adoption of ethanol as sole fuel for vehicles – the hydrated alcohol –, an important impetus came from the automotive industry, who launched in the end of 1970s, the car entirely run by alcohol. It is also in this phase that environmental concerns appear, both related to the production of sugar cane (control of residues and agricultural zoning), and to claims in favor of reduction of pollution in big cities through the elimination of tetra-ethyl lead, pollutant component present in gasoline[7].

[6] The main instruments utilized for conceding a wide and long-lasting supportive basis to the Program included tax exemption and special credit lines, directed not only to the ethanol-sugar sector but also, chemical, automotive and heavy mechanics ones (BNDES, 1995).

[7] The analysis on biofuels in general is accompanied by the discussion over the importance of social and environmental aspects involved in theis production and consumption. This is a fundamental question in the recent context in which importing markets have been making some allegations that biofuels production poses some negative social and environmental impacts. In the Brazilian case, Macedo (2005) states that such negative impacts are being fought, in face of the technological advances of the recent years, allowing the sugar cane agro-industry to overcome the cristicism. To a critical analysis over the social and environmental aspects involved in the production of biofuels in Brazil see Assis e Zucarelli (2007).

Proalcool's third phase is extended from 1987 to 1995 and was initiated in the middle of an era of uncertainties for continuing the Program, deflagrated by the rough reduction of public resources invested in Proalcool, among other factors. At the end of 1989 occurs what Paixão (1996) denominates 'alcohol shock'[8], initiating a long duration crisis and a concerning retrocession of the Program, at odds with the international tendency of investing in the search of alternative and renewable sources of energy (BNDES, 1995). This very retrocession must be seen as part of the new role envisaged by the State, passing from normative to indicative, according to recommendation of various international agencies that proclaimed the economic liberalization in the 1990s.

From then on, elimination of governmental control and planning mechanisms for production was gradual, helping to the incitement of the crisis in the ethanol fuel industry, traditionally accustomed to State protection. Severe criticism that was being directed at Proalcool were even more highlighted, regarding its high bureaucracy and the concession of sound subsidies from the government, an account paid by society due to the maintenance of a forced competitiveness of alcohol over petrol gas (Paixão, 1996).

Some data in defense of Proalcool must also be presented. According to data made available at Procana (2004), for instance, the total investment of US$ 11,7 billion, since its creation, allowed the country to save around US$ 38 billion until the end of the 1990s, through importing substitution. Macedo (2005) also defends that the substitution of petrol for alcohol, between 1976 and 2004, was responsible for an economy of up to US$ 121,3 billion. Considering the execution of a sound evaluation about the whole period Waack and Neves (1998, p. 10) affirm that such task is a difficult and challenging one.

It is interesting to reckon that while in other countries the size and stability of domestic market exerted a key role for the posterior development of strategy directed at the foreign market, the case of ethanol fuel industry in Brazil evolved in the opposite manner, in which his historical leadership as sugar producer and exporter provided the basis for the development of a dynamic domestic ethanol industry (Martines-Filho *et al*., 2006).

We sustain that, despite the criticism, the recent valorization of ethanol fuel as a product owes much to public policies specifically delineated for the sector, basically through investments made during Proalcool. In this sense, we defend, moreover, that the country was well-succeeded for being capable of entering a new technology in its initial stage, enjoying a window of opportunity opened under the shape of a world energy crisis. In this sense we argue that another important feature of Proalcool was the launching of the first initiatives that later represented the basis for the sustainable innovation system for ethanol fuel in the country, noticeable at the present moment.

This recent valorization is comprehended in the fourth phase in the evolution of the sugar cane agro-industry, which started in 2000s and can be extended until nowadays. After the crisis, new delineation was necessary as well as a revitalization of the product (Simões, 2007). The

[8] Long queues were formed in gas stations all over the country. Paradoxically, at the end of the 1980s Brazil had to adopt two strategies in order to overcome this difficult situation: it started importing methanol and adding 5% of gasoline to hydrated alcohol. Proalcool entered into a serious confidentiality crisis.

fourth phase initiated with the deregulation process[9] of the sector, which was postponed three times due to conflicts of interest and opinion at the time (Barros and Moraes, 2002).

Even if introduced in a slow and troubled manner, according to Fairbanks (2006), this liberalization process forced producers to move from a convenient situation in which they were used to production quotas, established prices, subsidies and monopoly for exporting sugar to a new situation of free market. Inadequately conducted this liberalization process led to a new crisis in the sector in 1999/2000.

The sector moved to the adoption of new strategies in this new context, involving the creation of commercialization centers, the acceleration of the concentration process, product differentiation, productive diversification, outsourcing and mechanization in agriculture (Vian, 2003). Cooperative initiatives have also been intensified, leading to the creation in 2006 of the Local Productive Arrangement of Alcohol (APLA, in Portuguese) in Piracicaba, congregating distilleries, industries, R&D institutes and so forth.

These new strategies were based on heavy investments in R&D. Such observations clash with more simple interpretation that reject developments in the agriculture field as intensive in innovation, as well as those that discard the importance that developing countries invest in R&D and in technological innovation, defending they should limit themselves to the mere acquisition of technologies from more advanced countries. In the specific case of the agro-industrial sugar-ethanol sector, it is the only one in which Brazil dominates all necessary technologies for production since raw materials, going to the selection and genetic improvement of sugar cane varieties, up to final goods of consumption. Brazil, therefore, represents a case that refutes this kind of rhetoric, since it was the intensive investment in R&D that allowed that the country stands out in one activity according to its particularities, in the agricultural field, being nowadays even adopted abroad.

Figure 1 illustrates the components of the Brazilian SI for ethanol fuel, without mentioning any hierarchy aspects, as we defend the systemic character of the innovative process, to which the most diverse actors contribute, possessing a total interactive and interdependent relationship.

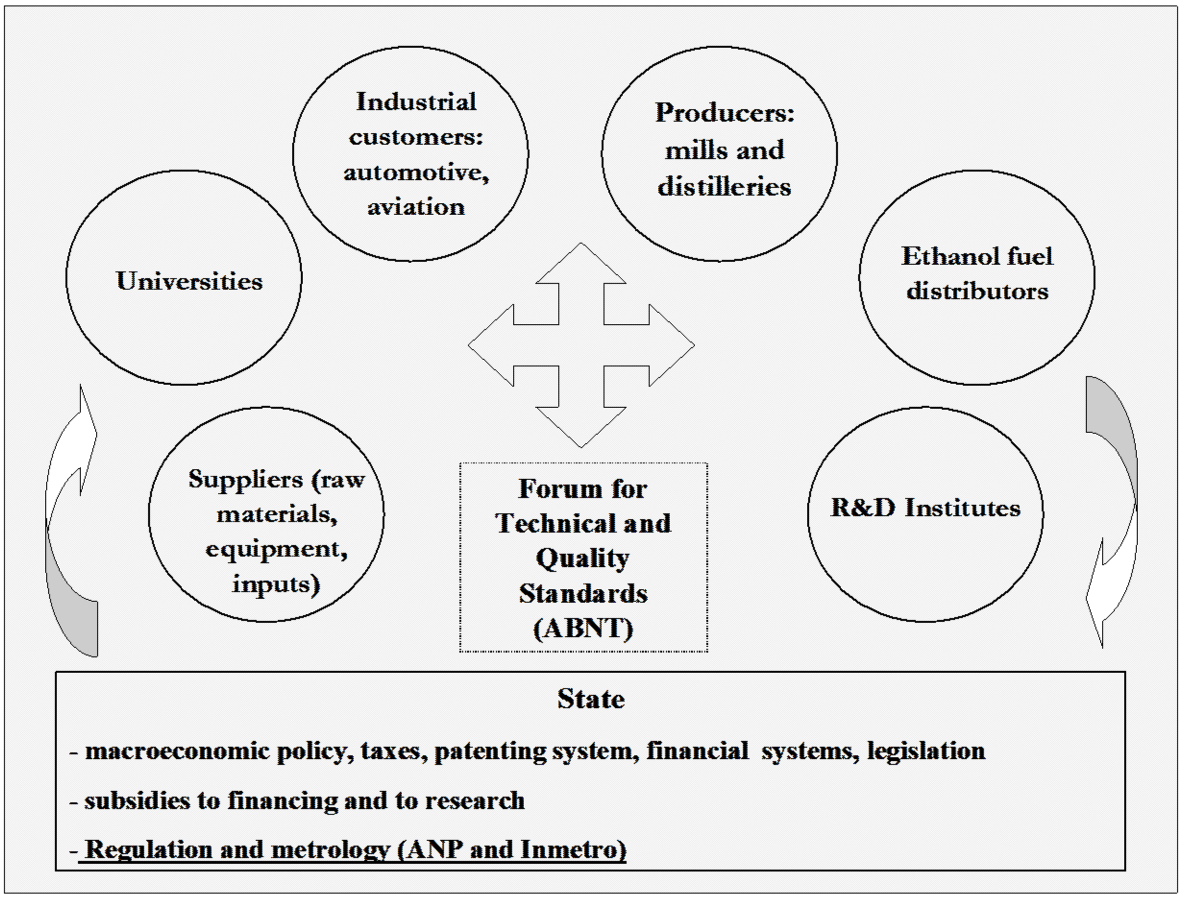
The aim of Figure 1 is to stress the role of the State in the SI for ethanol fuel, and its pervasive performance passing through the most diverse activities – going from the elaboration of macroeconomic policies that affect the dynamism of the innovative process until its participation in the concession of subsidies to research dedicated to technological development.

Still with regards to Figure 1, emphasis shall be given to those actors that act in the technical standardization process of ethanol fuel. Besides the obvious participation of mills and distilleries, and of other actors involved, we have tried to focus three organisms directly associated to this kind of activity: ABNT (national forum for the elaboration of technical standards on a voluntary basis), ANP (agency responsible for regulating the sector, including through the elaboration of technical regulations, on a compulsory basis) and Inmetro (national

[9] In August 1997, Law 9.478 opened the oil and natural gas market in Brazil, aiming at promoting more competition in these sectors. At the same time, two institutions were established: the National Council of Energy Policy (CNPE, in Portuguese), and the National Agency for Oil (now called National Agency for Oil, Natural Gas and Biofuels, ANP), with effects over the competitiveness of the ethanol fuel sector.

metrology institute in Brazil, responsible for the development of the metrological standard for ethanol fuel, the CRM – certified reference material)[10].

Figure 1 – Brazilian System of Innovation for Ethanol Fuel



Before we move on to discuss the standardization process into more depth, it is necessary to explore in more detail the innovative capacity of some selected elements in this productive chain. The high investment in R&D is one of the preponderant factors for the success and growth of the sector. Martines-Filho *et al*. (2006) show that the productivity of sugar cane and of the industrial activity in this sector have grown, respectively, at a rate of 2,3% and 1,17% per year between 1975 and 2004. Explanation for such growth rates lays on aspects such as the development of new varieties, the introduction of biological control of species, management

[10] In metrology, the CRM is the similar concept of Standard, when applied to chemical metrology. It is defined as the reference material accompanied by a certificate with one or more property values, and certified by a procedure that establishes its traceability to the exact obtainment of the unit in which the property values are expressed, and each certified value is accompanied by an uncertainty to a established confidence level.

improvements and soil selection. Data presented at the institutional video of UNICA state that investments in innovation reach up to around US$ 40 billion/year, corroborating our argument.

The innovative capacity of the ethanol fuel agro-industry must be understood in face of two premises. The first one is related to its characterization as a homogeneous product, whose innovative dynamics can be fit in the proposal of Utterback (1994). For this particular case the author develops the concept of ‘enabling technology’ – parallel to his definition of dominant design –, characterized as the one whose focus is directed to technological effort and to experimentation during the productive process, more concentrated, therefore, on process improvements that in product innovation and design. Utterback adds, still, that process innovations exert in this case a more profound impact over production, as opposed to what occurs in the production of differentiated goods, since this last one involves more process stages than the first one.

The second premise adopted for the purpose of the present analysis refers to the way by which technological accumulation is conducted in this agro-industry, adopting the hypothesis that this sector presents several characteristics that make it more similar to the classification of ‘suppliers dominated’ firms, as proposed by Bell e Pavitt (1993), even if we do recognize that it also presents a few characteristics associated to ‘scale intensive’ or ‘scientific base’ firms. In other words, we conclude that the accomplishment of most innovations come from suppliers – of raw materials, chemical inputs and equipment –, presenting, still, consequences over industries that produce goods that utilize ethanol fuel as a consumption good, as the automotive and more recently aviation industry.

We sustain, moreover, the hypothesis that the sector has been getting closer to those cases in which the technological accumulation process has been facing an evolution that allows that more dynamic and complex innovations be introduced – as those from more advanced sectors, as biotechnology and automation.

With the aim of demonstrating the argument here stated, a brief presentation shall follow, with emphasis over some of the most prominent examples in each link of the chain and their respective innovative initiatives – suppliers of raw materials, of chemical inputs and of equipment and, finally, in industries that use ethanol fuel as a consumption good.

The first R&D initiatives in the sector date from the 1960s, when all distillery projects was either French or German, and a Brazilian producer decided to invest for the development of a national technology. This technology was developed by the chemical engineer Jaime Lacerda, considered the creator of the national technology used until nowadays by producers of distillery columns (Procana, 2004).

The main advances in technology process since then have come from initiatives directed at a better usage of the main raw material – the sugar cane. In 1971 the first strategies concerning the investments in R&D dedicated to new sugar cane varieties can be found, starting with the launching by the government of the Program Planalsucar. In parallel, the cooperative Copersucar created the ‘Copersucar Technology Center’ (CTC, now called Sugar Cane Technology Center), another essential actor for the conduction of researches that allowed the expansion of the sector. After the closure of Planalsucar in the 1990s, as part of the deregulation process, the Inter-institutional Net for the Development of the Ethanol-Sugar Sector (RIDESA, in Portuguese), composed of eight universities, absorbed the previous research work of Planalsucar with the creation of the Program for the Genetic Improvement of Sugar Cane (PMGCA, in Portuguese).

This is how, through studies conducted in the scope of Planalsucar, of PMGCA and by CTC, among others, in the last thirty years, national varieties for sugar cane have been introduced in the market, with the best productivity indexes and resistance to diseases.

According to Macedo (2005), R&D activities have allowed the cultivation of over 500 varieties of sugar cane, 51 of which developed in the last 10 years. He also states that the country stands out among other sugar cane producers due to investments in biotechnology with the development of genetically modified varieties (not commercialized yet because of a lack of legislation that allows this kind of advances) since the 1990s and also with the identification, by Brazilian laboratories of 40.000 genes of sugar cane in 2003.

Concerning the production of equipment, strategies conducted by the national leader in the production of capital goods for the ethanol-sugar sector – 'Dedini S/A Indústrias de Base' deserve attention. According to Dedini's Vice-president of Technology and Development, José Luiz Olivério, this firm invests around 4% of its annual revenue in R&D. It is this kind of strategy that has taken Dedini to the leading position, as it offers all necessary equipment to the establishment of mills and distilleries, including peripheric items and process technology. Dedini supplies over 80% of original equipment of all mills installed in Brazil, besides exporting to diverse countries. This is an outstanding feature, since: "the capacity of introducing commercially well-succeeded capital goods is conceived as one of many possible indicators of 'strength' in a given innovation system" (Dalum, 1992).

Dedini also supplies plants in accordance to specifications established at ANP Resolution 36/2005, facilitating the compliance of the Brazilian products to such regulation. This is one important evidence of the influence of regulatory mechanisms in the selection environment of innovations (to be further discussed on section 3). Moreover, such strategy represents an important source for the diffusion of the technological innovations that have been introduced, usually according to demands of producers.

Smar is another firm that deserves attention as it is the national leader and one the world greatest firms in the segment of equipment for electronic control of industrial processes. The firm developed some of the most efficient softwares for process management in the mills, and its leadership is supported by a strategy that comprises the investment of up to 12% of its annual revenue of aound US$ 60 millions in R&D. Smar also occupies the first place in the patent ranking of the sector – approximately 50.

Another innovation that comes from suppliers for the ethanol fuel sector is the one that belong to the chemical segment: Clariant, responsible for the development of the orange pigment AR4, which identifies anhydrous alcohol without interfering in the product or with the combustion in automotive engines, according to the determination of ANP (see section 3). This pigment aims at avoiding the deviation of anhydrous alcohol, free from taxes, to a posterior sale as hydrated alcohol, taxes at the origin, generating improper profits in the mixture to gasoline. In this case the technological innovation was developed after a request of the regulatory body, who created an opportunity for increasing the innovative capacity in the segment of chemical inputs suppliers.

The spill over effects on other industries that utilize ethanol fuel as a consumption good must be also emphasized, as this is one of the most significant mechanisms for the diffusion of the innovation that has been introduced, as well as to evaluate whether the firm has been well-succeeded in the corresponding 'selection environment'.

The first segment to be looked into is the automotive, the main consumer of ethanol fuel. In 1979, researchers from the University of São Paulo (USP) developed a brand new technology, the ‘Otto Cycle’ engines run by hydrated fuel. Sound investments were necessary at that time, with special attention to those made by a public institution, the Airspace Technology Center (CTA, in Portuguese), so that in less than four years, most problems identified at that time were overcome, what also allowed for the technical continuation of Proalcool (Paixão, 1996).

In case these problems had not been overcome, we may infer that maybe at that moment the very usage of ethanol as a sole fuel – considered a technological innovation itself – could have been considered inadequate and could have been fated to failure in face of the mechanisms that act on the selection environment: the market and the regulatory devices.

Despite the initial difficulties and the crises observed during its evolution, the product consolidated until new impetus appeared for the sector in 2003, when after almost tem years of technological development for bifuels automotive engines (‘flex-fuel’) , this important innovation was introduced in the market. With this launching, developed by the firms Magneti Marelli and Bosch (that act in the segment of automotive technology), consumers can now choose either for gasoline or ethanol with no additional costs, and their decision depends uniquely on the price relation between both fuels[11].

The flex-fuel technology had been originally developed in USA by the Corporate Average Fuel Economy (CAFE)[12], in the 1980s. Nevertheless, since the North-American technology was more complex and high-costly national assemblers decided to invest resources in the development of a similar technology, what could have been later on obtained through a series of studies that led to a completely new flex-fuel system at a much lower cost (Junior, 2007).

More recently the segment of small airplanes has been also investing in technological innovations, with emphasis to aircraft engines run on pure ethanol. In 2002 the first initiatives with this aim were started and between 2004 and 2005, the first aircraft scale produced was launched – ‘Ipanema’, an airplane directed at agricultural ends, developed by CTA in partnership with the producer Neiva, became the first one to be run on ethanol, the same one used in cars. Ipanema received two awards due to its innovative character – a national one and an international one. There is one more innovation under way – researches have started to develop the ‘flex-fuel’ small airplane, a partnership between CTA and the firm Magnetti Marelli.

Several other technological innovations are being introduced as a result of spill over effects from the ethanol fuel sector, such as the possibilities presented by sucrose that are, as defended by Macedo (2005; 2007), much greater that those implemented in the present. Produced in more than 80 countries, its production cost is quite low, notably in Brazil. For being a quite versatile raw material it may function as basis for various constructive ‘blocks’ of molecules of interest. Their derived products, moreover, may present lower environmental impacts than petrochemicals. It is in this context that Copersucar has recently implemented the first factory of biodegradable plastics (PHB), from sugar – an innovation with strong environmental claims.

It is also important to highlight the possibility of retaking alcohol-chemistry, whose development had been paralyzed in the 1980s, due to the relative high costs of ethanol at that time. As Macedo (2005) points out, it comprises widely known processes, with no high complexity, whose technologies are already dominated in the country .

[11] Nowadays, around 70% of the annual production of cars in Brazil belong to this category (ANFAVEA, 2008).
[12] More information available at <http://www.nhtsa.dot.gov/cars/rules/café/overview.htm>, acess on 03/12/2008.

For the future, researchers point at a new role to be played by ethanol fuel, as it may represent the transition fuel for hydrogen cells. It is in this context that Macedo (2007) sustains that, even though ethanol production has reached a ‘mature’ stage in Brazil, there is plenty of room for gradual advances over the technologies under usage, besides the obtainment of gains with the launching of new technologies.

The examples of technological innovations briefly mentioned in this section, introduced by different segments that compose or are related to the Brazilian industry of ethanol fuel were responsible for the construction of competitive advantages that allowed a leading position for the industry. They also show important interactions among SI agents, such as mills and distilleries, producers of equipment and inputs, universities, public institutes, and regulatory agency. This last one as much as other actors that act in the standardization process are now the main focus of our analysis.

3. Standardization in the Brazilian System of Innovation for Ethanol Fuel

In order to better demonstrate the importance of the standardization process for the Brazilian SI for ethanol fuel, some issues must be raised on the relationship between standardization and innovation, focusing on the role played by the government within this process.

As mentioned in the first section, new technological paradigms open a wide range of technological possibilities for countries and as it gets mature, technology becomes more standardized and diffused. It is during the diffusion process that the macroeconomic effects of an innovation – such as job creation and economic growth – can be observed; usually years after its introduction. This is when imitators start realizing the profitable potential of the new product or process and envisage heavy investments for that technology (Freeman, 2003).

More conservative analyses on the diffusion process make an analogy to the occurrence of an ‘epidemic disease’ within a population. Such analyses conceive a S-shaped diffusion curve, adopting the hypothesis that its rate is faster in the middle of the process when compared both to its beginning and to its final stage. Criticism must be directed at these traditional analytical models, since their view neglects both the changes that occur in the environment during the diffusion process and those that occur at the original innovation itself (Freeman, 2003; Possas, 1989).

Nelson and Winter (1982) sustain that both the course and the rhythm of the diffusion process are not easily given, and will be determined by the combination of elements such as: profitability expected by firms of the sector; consumers’ preferences and existing regulatory devices, as well as the imitation process.

Some of the positive externalities of adopting a certain technology are associated to the perspective of interactive agents, learning effects, benefits for consumers related to the number of agents that utilize it. In the productive side, the standardization of a technology generates increasing returns, referred to the accumulation of knowledge and capabilities and reducing costs. Technology standards are also beneficial for facilitating the interconnection and the formation of wider nets, besides reducing risks faced by consumers of the new technology (Lundvall, 1992; Cowan and Cowan, 1998; Bassanini and Dosi, 1998; Shapiro and Varian, 1999).

Technical standards that specify the requirements with which products must comply are necessary, moreover, to allow the commercialization among anonymous economic agents, as the parties involved in the transaction need to be sure of the nature and quality of tradable goods (WTO, 2005).

The success of a diffusion process intimately depends on what happens in the ‘selection environment’ (Nelson and Winter, 1982). After the firm has decided to invest on a certain innovation, its competitive strategy shall be evaluated by those mechanisms responsible for selecting well-succeeded firms from those that are not: the market, the very resultant competition process and regulatory standards.

Regulatory standards of technical nature lay on the focus of the present article. They will exert a profound influence over the posterior rhythm of technological progress, since a technical standard represents a technological choice itself. Policy makers must be aware of this fact, under risk of merely imposing technical regulations without the duly evaluation with respect to the potential impacts over innovative activity and over technological development. Its role may be described as an analogy to a combination of ‘stick and carrot’ – representing, respectively, the imposition of regulatory instruments and the investment in R&D associated to these policies (Gregersen, 1992).

Public investments in R&D are necessary in particular to what refers to certain niches that would find no support from the private sector, mostly in technologies of public good character and those related to laboratory infrastructure that support regulatory activities – mainly in the field of metrology[13] (Tassey, 2005). Among others, the logic of the performance of the ‘carrot’ side of this role is based on its importance for the transfer of technologies developed by the State to industry and also in face of their strategic character in paving the way to the introduction of other technological innovations by firms.

With regards to technical standards imposed by the public sector – the public standards or technical regulations – they are associated to societal needs, to cohibiting information asymmetry and deceptive practices to consumers. Viewed as a State intervention and based on a mechanism of enforcement, this kind of policy is then considered as a ‘stick’ device and finds support on the idea that producers possess more information about products than consumers and that many societal objectives can not be reached otherwise (protection of environment, of plant and animal health, for instance). State then tries, through regulatory policies, to provide a more confidential and balanced environment for trade exchange.

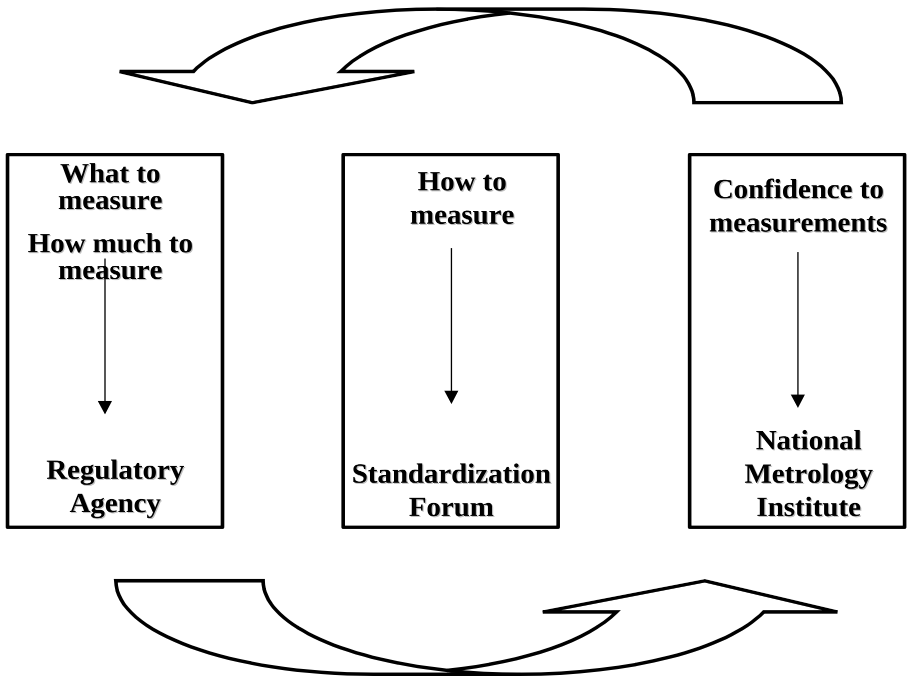
Under this perspective we may cpnclude that this specific role of the State as a regulatory agent brings some important analytical elements for the innovative process, due to its influences in both the selection environment of innovations and for their later diffusion. The consequences for paradigmatic change and the catching-up process must also be reckoned.

The mechanism of the standardization process as a whole can be understood by Figure 2. Technical parameters to be monitored for the analysis of product quality (what to measure), as well as the limits they must present (how much to measure), are established by regulatory agencies on a mandatory basis. Analytical methods to conduct these measurements are developed in the scope of the standardization forum, a voluntary activity. Finally the guarantee of this whole

[13] Metrology: pertains all theoretical and practical aspects related to measurement, whatever the uncertainty, in any field of science or technology (JCGM, 2008).

process – its traceability[14] – and associated confidence are conceived by a robust metrology basis, supplied by national metrology institute (NMI), usually a public entity.

Figure 2: Technical Standardization Process: Synergy between Metrology, Standardization and Regulation



Adapted from Daroda (2008)

More recently it is being emphasized the need that this whole framework acts strategically over the competitiveness of Brazilian industry. The fundamental role of metrology and of technical standardization became more evident when we started debating the initiative of transforming ethanol fuel into international commodity, aspired by its producers, in the search of greater competitiveness. For the success of this initiative, some challenges must be overcome, as the creation of a significant number of suppliers, aiming at avoiding supply crisis, as well as the establishment of technical standards for the product, so it can be commercialized in accordance to clear quality requirements. The importance of this second challenge becomes clearer in face of the following proposition by Swann (1999, p. 14):

> *"Minimum quality or quality discrimination standards can - more generally – reduce what economists call transaction costs. If the standard defines the product in a way that reduces buyer uncertainty, then first the risk to the buyer is reduced, and second there is less need for the buyer to spend time*

[14] According to the International Vocabulary of Metrology metrological traceability is defined as "property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty" (JCGM, 2008, p. 29).

and money evaluating the product before purchase. Consider a commodity market, for example: how could it exist in the absence of standards? Traders must be able to buy and sell large volumes without even viewing their trades. This is only possible if there is complete confidence about what it is that is being traded. That presumes a clearly defined standard grade, and certification that all produce traded meets that grade".

From the statement above the importance of the existence of standards that promote the necessary confidence to transactions that occur in a commodity market becomes clearer. It is then, in face of the strategy of raising ethanol fuel to an international commodity status that the relevance of well-defined standards is even more prominent. It is more specifically through a deep analysis about this challenge that we may better understand the implications of the standardization process over the competitiveness of a given industry, with direct effects on its innovative capacity.

To start this analysis, the vision of the main actors involved in this strategy will be highlighted, as a result of the case-study that has been conducted[15]. The main conclusion from this study was that well-defined technical specifications in the world market are of huge importance for promoting the 'commoditization' of ethanol fuel. According to the President of APLA, Luciano Tavares, this involves adjustments in the production processes with direct effects over production costs. He informs that the distillery process utilized by 70% of Brazilian producers – 'hexan cycle' – usually does not attend to the specifications of importing markets, and for that a more expensive process must be used – 'molecular bolter'. To comply with the requirements of these markets, therefore, sound investments are necessary, a difficult task to small producers.

We now live in a world where divergent specifications to ethanol fuel exist in the market, in a context in which there is no common standard for the product worldwide. Divergences regard not only the usage of different measurement units, but also the establishment of different characteristics in each specification as well as the stipulation of different limits of content. An astonishing lack of information can be observed and many times more rigorous specifications – as those that springs from regulations formulated to alcohol for human consumption – are also demanded by consumers of ethanol for fuel. Another problem must be emphasized, concerning the lack of confidence in the analysis that are conducted by the laboratories involved in this task.

According to the expert in ethanol standardization and quality, José Félix da Silva Junior, representative of UNICA/Copersucar, two aspects must be singled out. Firstly with respect to the different measurement units utilized. They are sometimes so rough that it get necessary to transform them into other ones that have some meaning. The second aspect is related to analytical methods, many of which have been determined to petrol analysis – not applicable to ethanol, therefore –, and are uniquely demanded due to a total lack of technical knowledge on the matter. Other methods, he affirms, are totally unnecessary what could open a possibility for the usage of

[15] As part of this case-study, interviews have been conducted with the following actors: Luciano Santos Tavares de Almeida (Arranjo Produtivo Local do Álcool, APLA); Wokimar Teixeira Garcia (Centro de Tecnologia Canavieira, CTC); Achiles Aparecido Mollon and Edmilson Lacerda (Usina Costa Pinto, Group Cosan); Humberto Brandi (Inmetro); Cristina Almeida Rego Nascimento (ANP); José Félix da Silva Junior (Copersucar and ÚNICA); Marcia Cristina de Oliveira (Associação Brasileira de Normas Técnicas, ABNT).

simpler methods. As it does not occur yet, only big and well-equipped laboratories are capable of analyzing a certain sample.

In the absence of a harmonized standard for the product, most distilleries develop a Standard of their own, based on ANP's regulation, as informed by Wokimar Teixeira Garcia, Researcher at CTC. According to him, there is still to much lack of information among importers and in this context negotiation is held on a case by case basis, and it is not always that the Brazilian producer tries to show that ANP's specifications are sufficient and ends up by accepting the requirement demands by importing markets, quite often improper.

Additional troubling feature lays on the fact that while in Brazil technical specifications for the product are define on a compulsory basis, it is a different situation in foreign markets where such definition is mostly settled by actors in the voluntary sphere. It means that the discussion on the legitimacy of their requirements are not conducted as a governments negotiation, and it is solely up to the producer to demonstrate the quality of his product and, in this case, the importer is sovereign to decide whether the product complies with his quality parameters or not. In a negotiation of this kind, advantage goes to those with more bargain power, usually more traditional producers.

Evidences on how industry has been dealing with the above mentioned questions may be obtained through an analysis of Group Cosan, national leader and one of the greatest producers of sugar and ethanol in the world. They posses a specification of their own, developed with basis on ANP Regulation . Whenever a purchase request is received by their commercial department they check whether the technical specifications match to ANP regulation. In case they do not match, a research is initiated among the distilleries of the Group to check if there is anyone who may comply with such specification.

In case it is not possible to comply with the specification, a negotiation is started with the offer of Cosan's 'standard', what may even involve the issuing of a sample when necessary. Cosan's strategy is usually well-succeeded in face of the recognition of their quality and their tradition in the market. In the opinion of Achiles Aparecido Mollon, Laboratory Corporate Manager and Edmilson Lacerda, Production Manager, both from the mill Costa Pinto of Cosan Group, the development of a CRM would be an important advance for ethanol fuel market, in terms of quality and safety of the product. Moreover the development of an international standard for the product under the scope of ISO would be of huge importance in their opinion, since they have identified nowadays around 15 different technical specification for ethanol fuel, for just five different types of the product.

It is important to retake some aspects of Proalcool, with the aim of highlighting some difficulties that remain since then, reffered to the Brazilian historical in the standardization of ethanol fuel. In a study developed by Anciães (1978), it was emphasized the need of conducting studies and research directed at the elaboration of technical specification for alcohol (not only fuel but those used in other industries, as the chemical, for instance).

The lack to specific technical standards causes significant equivocation – as for example the usage of technical standards elaborated for food alcohol in the production of ethanol fuel. This lack of specification has its roots in the lack of understanding on its importance, at one side, and on the deficient Basic Industrial Technology (TIB, in Portuguese[16]) at the time.

[16] In Brazil the term TIB comprises the activities of metrology, technical standardization, technical regulation, conformity assessment, management technologies and intellectual property.

Concerns with technical requirements for ethanol fuel was restrict, at a first moment, to the private sector, interested in advancing on the quality of their products, searching for greater competitiveness. In this process, an important actor was CTC, which introduced the first activities related to quality analysis, not only for alcohol but also for sugar, still in the 1980s. The initial motivation was to control the quality of mills and harmonize quality somehow. At the end of the 1990s, the implementation of ISO 9000 (quality management) e ISO 14000 (environmental management) started.

In the compulsory field, the first initiative of establishment of technical specifications for ethanol fuel dates of 1979, when the extinct National Council for Petroleum (CNP, in Portuguese) elaborated the Technical Regulation CNP 03/79, the first one specifically for ethanol fuel. This regulation was elaborated with basis on technical specifications defined by the private sector, process in which the participation of actors as CTC was fundamental.

Initially the methods that should be used for analyzing the compliance to the characteristics as defined in the technical regulations were determined at the very text of the document with no explicit mention to technical standards, as they did not exist yet. Only in 1986, during the third revision of Technical Regulation CNP 03/79, can one observe the first mention to standards in the scope of ABNT, as well as of other international organisms, directed at the establishment of test methods for the determination of the specifications for ethanol fuel.

In the same manner as the definition of analytical methods, the metrological basis for its support occurred a posteriori of the whole process. Heavy investments in the field of scientific metrology – and more specifically in the area of Chemistry –, essential for the advances in the field of technical standardization for ethanol fuel, had not been initiated and the Brazilian NMI, Inmetro, was still under implementation.

Despite such obstacles, ANP has been quite efficient in the regulation and surveillance of the product in the country, considered of high quality, with important effects on the competitiveness and inovativeness of industry. As an instance we mention the Agency's fight against the 'wet alcohol' fraud, which consists in the addition of water to anhydrous alcohol, from then on commercialized as hydrated alcohol. To fight against this fraud, ANP initiated the exigency of addition of a pigment in anhydrous alcohol and the usage of a label on gas stations warning consumers to observe whether the hydrated alcohol they are purchasing is limpid (Resolution ANP nº 36), and as has been previously discussed on section 2, it opened an opportunity so chemical inputs' producers could innovate. The result of this activity has been positive: non-conformities related to ethanol fuel, registered by ANP, decreased from 12,5%, in 2002, to 1,7%, in February 2008[17].

It is important to notice that the elaboration and revision processes of technical regulations and standards conducted, respectively, by ANP and ABNT, are held with a wide participation of the sectors interested in the theme, specially those from the private sector.

The technical content of specifications has not been through significant changes along these years, corroborating the character of homogeneous product of ethanol fuel, as previously defended. With respect to anhydrous ethanol, technical requirements defined by industry were accompanied by the evolution of technical regulations. The technical regulation for hydrated alcohol, by its turn, introduced in the 1980s, was considered at that time too harsh by producers,

[17] Information captured during interview with Cristina Nascimento, from ANP on 04/18/2008.

demanding a series of modification in the production chain. Despite the dissatisfaction of many producers, they all had to make adjustments and, for that, it was necessary to invest in technological innovation – in areas of the productive process such as distillation and fermentation.

This is one more example of the State as an agent in the technical standardization acting over the innovative process. Its initiative of regulating the sector created an opportunity for the introduction of subsequent technological innovations, necessary for the duly compliance to technical specifications determined on a mandatory basis.

Nevertheless, as presented in Figure 2, the success of the standardization process lays on the complementarity of the three spheres that compose it – the regulatory agency (defining parameters and their limits), technical standardization forum (establishing the analytical methods) and the national institute of metrology (offering guarantee and confidence to the whole process). In the specific case of the Brazilian ethanol fuel sector, the three actors that act in such spheres constitute, respectively, ANP, ABNT e Inmetro. The evolution of this theme in the country allows the conclusion that if the first sphere evolved in a regular manner, the second one evolved not so regularly and the last one practically had not been initiated until recently.

Without this solid metrological basis, the very analysis concerning the compliance to the requirements established by ANP is impaired due to the nonexistence of a reference standard that serves as a comparison basis to effectively evaluate whether the result obtained in the analysis is compatible to the desired level, given by the associate CRM, in this case.

Such obstacles, though, have only become more prominent with the increasing participation of Brazilian producers in the international market, when they face more strict requirements concerning the quality of tradable goods. Importing markets need the certification that their specifications are being considered, specially when it is related to a commodity, according to what is defended by Swann (1999). In this context, the credibility of the NMI is a fundamental condition for well-succeeded transactions in the international arena, under the threat that firms be subject to repeated analysis – increasing costs – what can only be made by those with greater bargain power and credibility.

Investments in R&D, necessary for the development of the first CRM for ethanol fuel lay on the basis of its standardization process, an imperative to its ‘commoditization’ in the international market and, moreover to help diffusing innovations introduced in the agro-industry, as the standard will congregate technological advances obtained during the evolution of ethanol production.

In Brazil, the organism responsible for conducting researches related to the development of the CRM – the NMI – is Inmetro. Until the beginning of the present century Inmetro did not possess – in the contrary to what already had been happening worldwide – a strong strategy for more advanced fields of metrology, such as Chemical Metrology, either to conduct R&D, this last one a pivotal condition for advances in the metrological area.

The activities held at the Brazilian NMI have always been more associated to legal metrology, with a mainly surveillance character. Nevertheless, a blank remains latent – the development of reference standards in areas of national interest, with a posterior and necessary transfer of technologies introduced to industry, fostering its innovative capacity. This situation started to change from the twenty-first century upwards, with the definition of new policies for the area, sustaining that the Brazilian NMI should pursue a wider strategy and not be just a mere deposit of ‘national standards’[18].

Activities involved in the elaboration of the ethanol fuel CRM are consonant with these new policies and for that actions inserted in the field of scientific and industrial metrology, with emphasis on the field of chemistry, had to be undertaken. Such strategies could only become concrete in face of the initiatives that had been taken at an effort of creating the Chemical Metrology Division of Inmetro (Dquim), in 2001.

With regards to this specific matter, we reckon the Brazilian technological delay, of approximately 100 years when compared to USA, for example, whose production of reference materials by its NMI – NIST, at that time denominated ‘National Bureau of Standards’ – had been initiated still in the beginning of the twentieth century (Alves and Moraes, s/d, p. 5).

Brazilian chemical industries had been asking for more actions from Inmetro in the field of standardization in chemical metrology since 1996, what shows a clear strategic vision on the importance to competitiveness. It is in this context that the necessary infrastructure to attend the demands of the industrial sector could be implemented. Special attention was directed at the ethanol fuel sector, including the formulation of a national strategy to advance towards the standardization of the product, in face of the need of increasing its competitiveness in tits he international scenery.

To capture the extent to which sound investments were made necessary, the development of a CRM for ethanol fuel must be understood as a complex process, as occurs to any chemical composition. In the last 5 years, the structuring of Dquim and the activities involved, either directly or indirectly, in the development of the CRM for ethanol fuel – mainly R&D resources – amount to about US$ 6,5 millions (counting on the investments predicted to be made in 2008 and 2009). Almost 70% of this amount referred to the acquisition of equipment, allowing the NMI to get structured to conduct the necessary R&D.

Such investments correspond to researches specifically developed for the creation of new methodologies to provide the analysis of the parameters as determined on the ANP Regulation for the fuel. According to Humberto Brandi, Director of Scientific and Industrial Metrology of Inmetro, this is how the Institute managed to introduce methodologies nonexistent until then, having been well-succeeded in the development of the CRM for anhydrous and hydrated alcohol, initially for five parameters of the ANP Regulation, made available to industry in the beginning of 2008. Such availability must be seen as an evidence of the inductive capacity of the State as supplier of R&D investments in the field of metrology, at a given NSI.

It is worth to emphasize that the commercialization of each CRM produced comprises a high technological content and also presents the possibility of gains obtained through the exports to other countries, as well as an economy in the purchase of CRM that would be imported in case the strategy of locally developing such artifacts had not been well-succeeded. Additional success must be singled out, with reference to the transfer of the developed technology to industry, who can from then on count on a product with high technological content, being able to aggregate value to its productive processes, since through this development it will possess a trusty instrument to measure the fuel’s quality.

[18] See Inmetro and CBM (2003).

4. Concluding Remarks

As we could observe along the discussion conducted at the present paper, the analysis on the case-study of the ethanol fuel industry shows an emblematic case in which Brazil, even though remains at an inferior level of development, was quite successful in the build-up of a specific SI for the sector, according to national interests and particularities. It is worth to mention that the roots of this construction must be traced back from the 1970s, when in reality there was no clear strategy for constructing a SI – as the concept had not yet been used –, but the most fundamental public policies for the sector started being structured.

Emphasis was given to the role of the State in helping the construction of the dynamic competitiveness of ethanol fuel industry, sustained in the generation of innovations, as well as on their diffusion. Firstly through the concession of public subsidies, during its stage as 'nascent industry' and, secondly, for having been the very State agencies responsible for investments that later on were translated into innovation and, therefore, of an inductive nature – whether through sugar cane varieties improvement programs or through technological research, as in the case of the development of alcohol fuel run engines (for cars and small airplanes as well).

Moreover, some examples of the State's performance in the creation of opportunities for the innovative capacity of the agro-industry – acting as a definer of regulatory devices – were singled out, as for instance ANP's requirement for the addition of a pigment on anhydrous alcohol, taking some chemical input suppliers to innovate in order to comply with the Agency's establishment.

Some challenges remain and must be strategically faced. For the purpose of the present research, emphasis is directed to the delay of the State in supplying the necessary investments for the construction of an important inductive mechanism for innovative activity – related to metrology, in its scientific field. This strategy was only included in the public policy for the sector more recently, in a more solid manner from 2006 onwards. Though late, it seem to us that the efforts that are being undertaken since then is of huge importance to the sustainability of the ethanol fuel agro-industry's competitiveness. We sustain the argument that the negligence on promoting activities for the technological standardization in this industry represented important obstacle, with potential negative reflections over their competitiveness, what became more visible after the country lost its leading position in the production of ethanol fuel (in 2006, USA took the position of world first ethanol fuel producer) and started facing some obstacles in the international market of ethanol fuel, resulting from disparities in the technical requirements demanded for the product.

It was exactly because of the perception of the need of overcoming this challenge that sound investments were directed to activities developed under the scope of the Brazilian NMI – Inmetro – with the aim of advancing in the production of the CRM – the standard – for ethanol fuel. We defend moreover that in case such initiative had not been pursued, the CRM for the product would have been solely developed by the North-American NMI, NIST, and Brazil would miss the chance of advancing in one more technological development.

With the conduction of a strong strategy, which counted on R&D expenditures of around US$ 6,5 millions accumulated within 6 years, Brazil has been well-succeeded in the development of the international standard for ethanol fuel, with significant effects over the competitiveness of this industry.

In this manner we sustain that the elevation of the country to the leading position in international standardization activities – contrary to what had been occurring with the mere import of CRM from other countries –, exerting strong influences in activities of national interest, as is the case of the ethanol fuel industry, shows itself as an important political initiative to be conducted in other selected sectors – as biodiesel for instance –, also in accordance to national and societal interests, with huge impact over the competitiveness and inovativeness of firms in a given NSI.

Our findings allows us to conclude that the activities involved in the standardization process play a strategic role for the sustainability of systems of innovation and as such sould be included in the formulation of industrial, technological and pro-innovation policies, specially in developing countries where the issue is still a recent one. We also encourage that further researches be conducted on these matters, as it has not been a present issue among academic studies.

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